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Storied or tier-like structure of certain dicotyledonous woods*

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A considerable number of dicotyledonous woods are characterized by a storied or tier-like arrangement of their secondary elements. Such woods exhibit on longitudinal section, typically on the tangential, fine transverse lines, bands or striations commonly called "ripple marks." These markings may be distinct to the unaided eye, may be at or near the limit of vision, or may require the lens. In some cases they may be more readily seen without the lens than with it, or they may be fairly distinct under the lens but indistinct or apparently absent under the compound microscope. In specimens with very dark and infiltrated heartwood the markings may be obscured there but show plainly in the sapwood; usually, though, they appear to best advantage in the heartwood.

In woods with this type of structure the cambial cells are in tangential as well as radial seriation and part or all of the elements to which they give rise preserve this arrangement. Ordinarily it is only in stems of considerable thickness that the tiers assume a marked regularity, but the diameter a stem must attain before the storied structure becomes pronounced is subject to wide variation, depending not only on the species but also on the rate of growth. In certain stems of Leguminosae and Zygophyllaceae the tiers were found to be fairly regular in what was apparently the second annual ring, less than one eighth inch from the pith. In general, though, this feature is wanting in the twigs of herbarium material.

The storied structure may not extend to all of the elements. In the extreme and also the most common form (Zygophyllaceae, Bignoniaceae, Leguminosae in large part, and others) the rays, vessel segments, tracheids, wood fibers, and wood parenchyma strands are all in horizontal seriation. On the tangential surface the cross sections of the rays appear as short, closely spaced, par-

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allel lines, often of very regular length and arrangement, while separating the tiers is a fine line of lighter or darker shade than the remainder of the wood. These lines are made by the junctions of the tiers of wood cells and vary in appearance according to the elements involved in a particular area, whether fibers with interlacing tips or vessel segments and wood parenchyma cells with abrupt terminations. In some instances, also, the local aggregations of pits in the fiber walls where the lumina become constricted tend to increase the refraction there and make the lines more distinct. According to Von Höhnel (1, p. 33) this is very pronounced in *Bocoa provacensis* Aubl. (*Inocarpus edulis* Forst.); his findings are confirmed by Wiesner (5, pp. 15, 950), who figures the pits. In the cases investigated by the present writer such pit-areas were noted in several woods, as for example, in *Machaerium*, *Physocalymma*(?), and *Erythrina*.

Where the rays are all storied they occupy the median portion of each tier, the height of which is usually considerably greater than the height of the rays. Consequently there is room for considerable variation in the height of the rays without interrupting the regularity of the transverse markings. It is not uncommon to find some of the rays grown together at the margins and thus occupying two or three stories, as for example, in *Cercis*, *Crescentia*, *Ormosia* and *Ougenia*. Where the rays are in perfect seriation, a section between two tiers misses them completely. In most instances, however, such a section shows rayless gaps, the width of which depends upon the regularity of stories.

In some storied woods, especially in the Bombacaceae, Malvaceae and Sterculiaceae, the rays are of two general sorts, large and small. Here only the low rays are in seriation and they may be so few, comparatively, and so over-shadowed by the large rays that the "ripple marks" are indistinct except in proper light and may be easily overlooked in casual inspection. In some of these woods the markings may be plainer without the lens than with it and, because of the very limited field under observation, may not be distinguishable at all under the compound microscope.

In both of these types the elements other than the rays are normally storied. The vessel segments and vascular tracheids correspond in length to the height of each tier, though occasional short segments are found which appear to be subdivisions. The wood parenchyma strands show a uniformity in length with the vessel segments, but in a few cases where parenchyma is scanty the vessel segments and tracheids (when present) seem to be entirely responsible for the "ripple marks." This was found to be the case in *Dalea spinosa* Gray, *Artemisia tridentata* Nutt., and *Bigelovia graveolens* Gray.

The number of parenchyma cells per strand is not constant but in most of the woods investigated was found to be two or four; sometimes only one (an intermediate or substitute fiber). It is not uncommon to find that the metatracheal strands are composed of two cells and the paratracheal of four. Where the parenchyma is abundant, the component cells of the strands may be uniformly disposed and thus give rise to a secondary seriation which, especially if the cells are large, is readily visible under the lens. In this case the height of the tiers in only one half or one fourth that of the ordinary tiers. In species of *Bombax*, *Ceiba* (*Eriodendron*) and *Heliocarpus* the number of cells per strand is four; in *Charpentiera*, *Diphysa* and *Lonchocarpus*, two; in *Gossypium* and *Pterocymbium*, two in the metatracheal and four in the paratrachea'. The same structure obtains in some of the finer-textured woods, but the small size of the cells usually renders it indistinct or invisible under the lens. It was found fairly distinct in *Ichthyomethia piscipula* (L.) Kuntze (mostly two cells per strand) and less so in *Tabebuia Guayacan* Hemsl. (four cells per strand).

The libriform fibers and fiber-tracheids (collectively, wood fibers) may or may not show distinct seriation in the tangential section. In all ordinary cases the fibers are much longer than the vessel segments or the height of the tiers. In many cases there is a widened middle portion equal to about one third of the total length of the fiber and corresponding to the length of the original cambial cell. The attenuated ends of the fibers of one tier are forced during elongation between the fibers of the tiers immediately above and below and, in consequence, a cross section through the middle portion of a tier will show (under the compound microscope) alternate rows of large and small cells, the latter being twice as many as the large ones. A section through the junction of two tiers will show fewer cells and they will be more nearly uniform in size. In many woods the fibers show a gradual instead of abrupt diminution in caliber and the feature just mentioned is absent or indistinct. It may require careful maceration to determine whether or not the fibers are storied, particularly in woods with irregular rays. The fact that the fibers are so interlaced and dove-tailed together prevents woods with storied structure from being weakened or made brittle thereby.

In *Herminiera elaphroxylon* Guill. & Perr., the wood cells ("palisade tracheids" of Jaensch, 3, p. 269) are parenchymatous and arranged in regular stories. Some of the cells are subdivided but not very regularly. The low uniseriate rays are storied while the large ones (which may contain vessels) are not. The vessel segments are mostly of the same length as the height of the tiers but according to Wiesner (5, p. 20) some of them may be subdivided. The wood fibers, which are distributed in narrow layers, are three times the length of the other elements and have localized pit areas at the constrictions. Solereder (6, p. 276) figures *Aeschynomene* sp. with the parenchymatous wood cells much pitted at the ends. The present writer did not have opportunity to study woods of this genus but found much the same structure in *Erythrina* spp., except that all or nearly all of the rays are large and the wood fibers in the scattered bands are apparently not storied. The parenchymatous cells making up the ground mass are large, thin-walled, blunt-ended, and usually subdivided into two cells about the vessels. The markings vary from distinct in some specimens to barely visible without lens in others.

Where the elements of the wood are definitely storied it is, of course, to be expected that the same arrangement will likewise appear in the secondary phloem. In the limited number of stems with bark examined by the writer this was found to be the case and in some instances, *Dalea spinosa* for example, the feature was more distinct on the inner surface of the bark than in the wood. An unusual case was found in *Olneya tesota* Gray, where the inner surface of the bark exhibits, under the lens, fine but distinct and fairly regular cross-lines (150–160 per inch) without, apparently, any corresponding structure in the wood. Under the compound microscope the vessel segments and wood parenchyma strands are indistinctly storied, but the rays and apparently the fibers are not, while the vertical elements of the secondary phloem are in horizontal seriation. The distinctness of the cross-lines in the inner layers of phloem was found to be largely due to highly refractive callus on the sieve plates.

The storied structure of wood occurs throughout a considerable range of families and orders as will appear from the following list, which is arranged according to the Engler and Gilg (1912) system of classification. The first numeral following the family refers to the number of different genera in which the feature has been noted by the writer; that in parentheses, to the total number reported.

1. URTICALES: Ulmaceae, 1 (1); Moraceae, 1 (1).
2. CENTROSPERMAE: Amarantaceae, 1 (1).
3. RHOEADALES: Moringaceae (1).
4. ROSALES: Rosaceae (1?); Leguminosae, 40 (51).
5. GERANIALES: Zygophyllaceae, 3 (4); Rutaceae, 1 (1); Simarubaceae, 3 (4); Meliaceae, 6 (7).
6. SAPINDALES: Hippocastanaceae, 1 (1); Sapindaceae (1).
7. MALVALES: Tiliaceae, 5 (8); Malvaceae, 4 (4); Bombacaceae, 3 (3); Sterculiaceae, 7 (8).
8. MYRTIFLORAE: Lythraceae, 1? (1?).
9. EBENALES: Ebenaceae, 1 (1).
10. TUBIFLORAE: Bignoniaceae, 3 (3).
11. CAMPANULATAE: Compositae, 3 (3).

Consideration of the above list leads to the conclusion that there is no close correlation between the form of wood structure under consideration and the various types of floral organization which serve as the basis for the classification followed. There seems to be a correlation, however, between this storied structure and certain types of differentiation of the wood elements. The vessel segments have abrupt ends and simple perforations, and the elongated or scalariform type of pitting is rarely found and then only in the tracheidal vessels and vascular tracheids. The wood fibers are for the most part provided with simple pits or with pits having only small and indistinct borders. The pits between vessels and parenchyma are usually small and half-bordered. It is also interesting to note that with very few exceptions (notably *Aesculus*, *Cercis*, *Cytisus*, *Diospyros* and *Tilia*) the woods are of tropical or subtropical origin.

There is no family, with the possible exception of the Zygophyllaceae (only a few woods of which were studied), in which all of the woods are characterized by horizontal ranking of their elements. In many cases it appears to be a generic character but more often it is specific only. A few instances have been noted where the feature is not constant for a given species and may be of only local occurrence in the same specimen. One of the best examples of this is furnished by *Swietenia*, where "ripple marks" exhibit wide variation in regularity and occurrence and are about as likely to be absent as present. In general, however, the constancy of the feature seems to bear a direct relation to the degree of regularity of the cross-markings. It is most dependable when all of the elements are involved and especially when the rays are fine and of uniform height.

In this investigation attention has been given to the elements storied, the regularity and visibility of the transverse markings and to the height of the tiers in each wood examined. In most instances only the gross and lens characters are given since they are most readily employed in practice. There are so many factors entering into the question of distinctness or visibility that the particular observations of the writer may not always apply. For instance, in *Guaiacum* the markings, though extremely fine, are distinct under the lens in the sapwood and may be indistinct or even invisible in very resinous heartwood. Usually the visibility is materially increased by moistening the surface, but in some instances the opposite effect is produced.

According to Von Höhnel (2, p. 2) the distance between the cross-lines varies from one half to one eleventh of a millimeter, and for a given species is constant. In order to determine whether or not there is a definite tier-height for each species the present writer counted the number of tiers per inch of length on the tangential section of every specimen examined. An inch, divided into quarters, was marked off and the count and recounts made under the lens for the entire inch, the quarter-marks serving as an additional check. In the larger specimens, at least two different inches were counted. In some instances the markings, being fairly distinct without a lens but indistinct with it, were counted with the naked eye or with the aid of a reading-glass. Where the rays are not in seriation the cross-lines are likely to be indistinct, and the most satisfactory results can be secured by counting the vessel segments. In the Zygophyllaceae the lines, though very uniform and readily visible under the lens, are so very closely spaced (about 250 per inch) that is it practically impossible to make an accurate count without the use of the compound microscope. By using low power and reflected light the smooth surface of a small specimen can be readily examined and measurements made without preparing thin sections.

Considerable variation in tier-height was found not only in different specimens of the same species but also in the same specimen. Even within a given inch of length the number per quarter may show a variation of from two to five as a result of the occasional to frequent bifurcation of the tiers, with consequent narrowing at the point of branching. The greatest variation in tier height within a species was noted in *Diospyros virginiana* L., where the counts per inch on eleven different specimens were as follows: 57, 57, 58–60, 60, 61, 62, 63, 66–68, 70–72, 72–74, 81–82; a maximum difference of 25 per inch, or nearly 45 per cent on the basis of the minimum. In only one other case did the variation exceed 20 per cent, and almost always it was less than 10 per cent.

In 86 woods of the Leguminosae the number of markings per inch were as follows: under 100, 29 per cent; 100 up to 125, 34 per cent; 125 up to 150, 21 per cent; 150 to 190, 12 per cent. Nearly every wood showing between 125 and 190 "ripple marks" per inch belongs to the Leguminosae. The investigated woods of the Zygophyllaceae have considerably more than 200 per inch, mostly about 250, and may, by means of this feature alone, be readily separated from all of the others. This fact has proved of practical value in distinguishing the wood of true lignum-vitae from its various substitutes.

The present investigation fails to confirm certain findings of other writers. Von Höhnel (1, p. 38) states that the rays are storied in *Parkinsonia*, but there was no evidence of this in the specimens examined by the writer. The grenadillo wood is referred to as "*Inga vera* W.?" (p. 39) but this is probably incorrect, inasmuch as various specimens of *Inga* spp. were found to be without any tendency to storied structure. The name "grenadillo" is applied to several woods, one of which is *Brya Ebenus* DC. Another wood with "ripple marks" was provisionally identified by the same author as *Conocarpus erecta* (Combretaceae), but authentic specimens of this species are wholly without this structure, as are all other representatives of the family that were examined. Wiesner (5, p. 997) states that in *Olea europea* L. the rays (under the lens) produce a fine wavy cross-striping on the tangential section. Specimens of the wood examined by the writer exhibit no tendency to "ripple marks," and Müller (Atlas der Holzstructur, 1888, pp. 88, 91) gives as one of the distinguishing features of this wood the irregularity in size of the rays. All of the foregoing woods are excluded from the table given below.

The only representative of the Lythraceae included in the list is *Physocalymma scaberrimum* Pohl, variously known as Brazilian tulip-wood, rose wood, "páo de rosa," "cego machada," "grão de porco" and "sebastião de arruda." Writers all seem to be in agreement in referring this wood to the species mentioned, but the specimens examined by the writer, which are evidently the same as those described by Wiesner (5, p. 975), appear to belong to the Leguminosae. They certainly do not resemble other available material of the Lythraceae.

Another wood of which there is some doubt is *Ferolia guyanensis* Aubl. (= *Parinarium* sp.) of the Rosaceae, mentioned by Von Höhnel (1, p. 43), who calls it "Ficatin- oder Königsholz." According to Stone (Timbers of Commerce, 1904, p. 101) this species supplies the wood from Guiana commonly known as "washiba" or bow-wood. Authentic specimens of washiba and bow-wood, collected by the Forestry Officer of British Guiana are *Tabebuia* spp. The tier height in the latter is about 0.25 mm., while according to Von Höhnel the height of the "Markstrahlstockwerke" in the wood of *Ferolia* is about 0.15 mm. If Von Höhnel's measurement refers only to the height of the rays the discrepancy disappears, since this agrees closely with the writer's observations. No other wood of the Rosaceae has been reported as having a tier-like structure.

The satinwood, *Chloroxylon Swietenia* DC., is listed with the Rutaceae (following Engler), rather than with the Meliaceae, because the wood so closely resembles those of the Rutaceae and has so little in common with the others. No other representative of the Rutaceae has been found with storied structure, while various representatives of the Meliaceae exhibit a more or less pronounced tendency in this direction. It is interesting to note, however, that the number of tiers per inch in the latter woods (so far as known to the writer) is between 45 and 55, while in the satinwood it is about 80.

Most of the woods with "ripple marks" belong to the Leguminosae. Following is a list of woods examined by the writer in which the storied structure was not observed, though a few (marked with an asterisk) have been reported by other writers and are included in the list. Some of the more common synonyms are placed in parentheses. These woods are: *Adenanthera*, *Albizzia**, *Bowdichia* (?), *Browneopsis*, *Cassia**, *Cercidium*, *Cercidophyllum*, *Cladastris* (*Copaiba*), *Copaifera*, *Cynometra*, *Daniellia* (?), *Dimorphandra*, *Enterolobium*, *Erythrophloeum*, *Eysenhardtia*, *Gleditsia*, *Gymnocladus*, *Haematoxylon*, *Inga* (see page 259), *Intsia*, *Kingiodendron* (?), *Lysiloma*, *Mimosa*, *Pahudia*, *Parkia**, *Parkinsonia*, *Peltogyne*, *Peltophorum* (?), *Piptadenia*, *Pithecolobium*, *Prioria*, *Prosopis*, *Pterodon*, *Robinia*, *Sindora* (*Vouacapoua*), *Zygia* (?).

In this investigation all of the woods in the extensive collections of the Yale School of Forestry were gone over. Since many of these are from tropical regions, of which our botanical knowledge is far from complete, it is by no means certain that all of the specific identifications are correct, though special effort was made to eliminate errors or indicate the doubtful cases. A considerable number of woods, mostly belonging to the Leguminosae, have been omitted because their botanical status has not been determined. The following table is published with a view of calling attention to an important feature of wood structure and with the hope of stimulating further investigation in this direction. The writer will appreciate assistance in correcting and extending the data.

NOTES: Under "rays not storied" are included woods which may have some of the rays, the small ones, in horizontal seriation. "Wood parenchyma cells storied" refers to the secondary seriation produced by the individual cells of the wood parenchyma strands; not visible without lens. "Fiber pits storied" refers to the horizontal seriation of special pit areas on the wood fibers. Where not noted does not necessarily mean that the feature is absent, since not all of the woods were examined microscopically. "Number of tiers per inch" applies exclusively to measurements by the writer and is the basis for "tier-height." A dash indicates a tendency. Data from other writers are credited to them and are as nearly complete as their descriptions will permit.

TABLE OF WOODS WITH TIER-LIKE STRUCTURE, SHOWING THE ELEMENTS STORIED, THE REGULARITY AND VISIBILITY OF THE TRANSVERSE LINES ("RIPPLE MARKS"), AND MEASUREMENTS OF TIER-HEIGHT

Scientific name	Common name	Country	Elements storied				Regularity of lines				Visibility				Measurements	
			All elements	Rays not storied	Wood parenchyma cells storied	Fiber pits storied	Regular	Fairly regular	Irregular	Local occurrence	Distinct—fairly so	Barely visible	Lens required	Indistinct with lens	Tier-height in mm.	Number of tiers per inch
AMARANTACEAE																
Charpentiera ovata Gaudich.	Papala	Hawaii		×	×			×					×		0.22–0.23	110–115
BIGNONIACEAE																
Crescentia cucurbitina L.	Black Calabash	Florida	×						×			×			0.22–0.23	110–115
" Cujete L.	Calabash	Porto Rico	×						×			×			0.21–0.22	115–120
Tabebuia Donnell-Smithii Rose	Prima vera	Central America	×					×	—	×		×			0.25	100
" Guayacan Hemsl.	Yellow guayacan	Panama	×		×		×				×				0.28	90– 92
" nodosa Griseb.	Toro-ratai	Argentina	×					×				×			0.17–0.18	140–145
" Palmeri Rose	Amapa prieto	West coast Mexico	×				×					×			0.20	124
" pentaphylla Hemsl.	(Roble)	Panama	×					×			×				0.29	84
" Schumanniana Urb.	Roble colorado	Porto Rico	×						×		×				0.29–0.31	80– 85
" sp. (No. 58)	Roble	Honduras	×				—	×			×				0.26–0.28	90– 96
" sp. (No. 97)	"	"	×					×			×				0.30	84
" sp. (No. 378)	"	Colombia	×				×				×				0.32–0.33	76– 78
" sp. (No. 351)	Apamate	Venezuela	×					×			×				0.32	78
" sp.	Hackia	British Guiana	×				×				×				0.26	94– 96
" sp.	Washiba Bow-wood	"	×				×				×				0.24	102–103
Tecoma araliacea DC.	Surinam Groenhart	"	×				×				×				0.33	74
" chrysantha DC.	Araguaney	Venezuela	×				×					×			0.21–0.22	115–120
" leucoxylon Mart.	Roble	Porto Rico	×						×				×		0.24–0.25	100–105
" obtusata DC. (*T. Ipe* Liais)	Lapacho	Argentina	×				×					×			0.21	120

Tecoma speciosa DC. (Höhnel, 1, p. 41)			×			×	×								0.25	
" stans Juss.		West Indies	×						×			×			0.21	120
" sp. (No. 930)	Lapacho	Argentina	×				×					×			0.22–0.23	112–115
" sp. (No. 1124)	"	"	×				×					×			0.24	105–107
" sp. (market specimen)	Bethabara	?	×				×					×			0.28	90
" sp. (2 specimens)		Brazil	×				×				×				0.25–0.26	95–100
BOMBACACEAE																
Bombax cyathophorum (Casar.) K. Schum. (*Pachira cyathophora* Casar.)	Imbirussi	Brazil		×	×			×			×			×	0.63–0.71	35– 40
Bombax insigne Wall.	Didu	Andamans		×	×			×			×			×	0.42–0.43	58– 60
" sp.? (No. 503)	Tolu	Colombia	—	×				×			×				0.40	63
" sp.? (No. 1570)	Majagua	"		×				×			×				0.42–0.45	55– 60
Ceiba pentandra (L.) Gärtn. (*Eriodendron anfractuosum* DC.)	Ceiba	Cuba		×	×			×				×			0.42	70
Cumingia philippinensis Vidal	Gapas-gapas	Philippine Islands	×				×				×				0.33	75
COMPOSITAE																
Artemisia tridentata Nutt.	Sage Brush	California		×				×					×		0.13 ±	200 ±
Baccharis sarothroides Gray		"		×				×				—	×		0.20–0.21	120–125
Bigelovia graveolens Gray		Colorado		×				×					×	×	0.13 ±	200 ±
EBENACEAE																
Diospyros virginiana L. (11 specimens)	Persimmon	Eastern United States	×				×	—	×		×				0.30–0.44	57– 82
HIPPOCASTANACEAE																
Aesculus octandra Marsh. (*A. flava* Ait.)	Buckeye	Central United States	×					×	×		×			×	0.36–0.43	58– 68
LEGUMINOSAE																
Albizzia procera (Willd.) Benth. (*Acacia procera* Willd.; Höhnel, 1, p. 38)		Tropical Asia	×												0.20	
Aeschynomene sp. (Solereder, 6, p. 275)	Solah	India		×		×		×								
Andira anthelmintica Benth. (Höhnel, 1, p. 35)		Brazil?	×				×								0.25	

TABLE OF WOODS WITH TIER-LIKE STRUCTURE, SHOWING THE ELEMENTS STORIED, THE REGULARITY AND VISIBILITY OF THE TRANSVERSE LINES ("RIPPLE MARKS"), AND MEASUREMENTS OF TIER-HEIGHT—*Continued*

Scientific name	Common name	Country	Elements storied				Regularity of lines				Visibility				Measurements	
			All elements	Rays not storied	Wood parenchyma cells storied	Fiber pits storied	Regular	Fairly regular	Irregular	Local occurrence	District—fairly so	Barely visible	Lens required	Indistinct with lens	Tier-height in mm.	Number of tiers per inch
LEGUMINOSAE—*Continued*																
ANDIRA INERMIS H. B. K.	Yaba	Cuba	X			X		X				X			0.26	93– 96
" " (Wiesner, 5, p. 947)	Partridge Wood	Tropical America	X				X						X			
APULEIA PRAECOX Mart.	Ibira pere	Argentina	X				X				X				0.24–0.26	95–105
" "	" "	"	X				X				X				0.28–0.29	85– 90
" sp. (No. 2497)	Faviero	Brazil	X				X				X				0.26	95
ARTHROCARPUM GRACILE Balf. f. (Saupe, 4)																
BAPHIA NITIDA Lodd. (Wiesner, 5, p. 936)	Camwood	Tropical Africa	X				X						X			
BAUHINIA LIGULATA Pittier		Panama	X					X			X				0.22–0.23	110–115
" RETICULATA DC. (Höhnel, 1, p. 37)		Africa?	X				X									
BELAIRIA MUCRONATA Griseb.	Yamaquey	Cuba	X				X						X		0.13–0.14	180–190
" SPINOSA A. Rich.	"	"	X				X						X		0.14	175–180
BRYA EBENUS DC.	Green Ebony	West Indies	X				X						X		0.15–0.16	160–165
CAESALPINIA CORIARIA Willd.	Divi-divi	Curaçao	X				X				X	—			0.21–0.23	110–120
" "	"	"	X						—	X		X			0.18	136
" "	"	India	X				X				X				0.19–0.20	126–132
" EBANO Karst.	Pao ferro	Brazil	X				X				X				0.25–0.26	95–100
" ECHINATA Lam.	Brazil-wood	"	X						X			X			0.28	90
" MELANOCARPA Griseb.	Guayacan	Argentina	X				X					—	X		0.18–0.19	130–135
" " ?	"	"	X				X					X			0.17–0.18	140–145
" SAPPAN L.	Sappan-wood	Philippine Islands	X						X	X		X			0.26	95

Caesalpinia tinctoria Domb. (Höhnel, 1, p. 37)		West Indies?	×					×							0.33	
Cassia Fistula L. (Höhnel, 1, p. 37)		India?	×					×							0.17	
Castanospermum australe A. Cunn. & Fraser	Black Bean	Australia	×				×		—	×	×	×			0.31–0.33	75–80
Centrolobium patinense Pittier	Amarillo de Guayaquil	Panama	×				×					×			0.23–0.24	105–110
“ robustum Mart.		Colombia	×				×					×			0.23	110
“ sp. ? (ten specimens)	Arariba	Brazil	×				×					×			0.21–0.25	100–200
“ sp. ?	Guayacan Jobo	South America	×												0.25	100
Cercis canadensis L.	Redbud	Central United States	×	—				×					×		0.16–0.17	150–160
“ Siliquastrum L. (Wiesner, 5, p. 930)	Judas Tree	Europe	×	—				× ×				×	×		0.20–0.24	
Coumarouna odorata Aubl.	Tonka Bean	British Guiana.	×				×				×				0.31	80
“ panamensis Pittier		Panama	×				×				×				0.30	82
“ sp.	Coumaru	Trinidad	×				×				×				0.28	90
Dalbergia Brownei Schinz.		Florida	×					×				×			0.21	120
“ hupeana Hance		China	×					×				×	—		0.18	135–140
“ latifolia Roxb.	Rosewood	India	×												0.16–0.17	150–160
“ nigra Allem. (Höhnel, 1, p. 37)		Brazil?	×				×	×				×			0.20	
Dalbergia retusa Hemsl.	Cocobola	Panama	×					×				×			0.18	138–140
“ sp. ? (two specimens)	“	Honduras	×				×					×			0.18–0.19	132–140
“ Sissoo Roxb.	Sissoo	India	×					×	—				×	×	0.16	155–158
Dalea spinosa Gray	Indigo Bark	Southwestern United States		×											0.17	150
Dialium indum L. (Höhnel, 1, p. 36)		Java?	×												0.33	
Diphysa carthagenensis Jacq.		Panama		×	×	×	×	×	—				×	—	0.16	155–160
Enterolobium Schombergkii Benth.		“	×							×	×			×		
“ sp. ?	Piñon	Colombia	×						×		×			×	0.33	75
Erythrina Crista-galli L.		Brazil		×		×		×			×			×	0.18	135–140
“ falcata Benth.	Ceibo	Argentina		×		×		×		×	×			×		
“ indica Lam.	Dap-dap	Philippine Islands		×		×		×			×				0.26–0.28	90– 95
“ monosperma Gaudich.	Wili-wili	Hawaii		×		×		×				—	×		0.19–0.20	125–130
“ aff. velutina Willd.		Curaçao		×		×		×			—	×			0.19	130

Table of woods with tier-like structure, showing the elements storied, the regularity and visibility of the transverse lines ("ripple marks"), and measurements of tier-height—*Continued*

Scientific name	Common name	Country	Elements storied				Regularity of lines				Visibility				Measurements	
			All elements	Rays not storied	Wood parenchyma cells storied	Fiber pits storied	Regular	Fairly regular	Irregular	Local occurrence	Distinct—fairly so	Barely visible	Lens required	Indistinct with lens	Tier-height in Mm.	Number of tiers per inch
LEGUMINOSAE—*Continued*																
Genista canariensis L. (Höhnel, 1, p. 38)			×													
Gourliea decorticans Gill. (four specimens)	Chañar	Argentina	×				×						×		0.13–0.15	165–185
Herminiera elaphroxylon Guill. & Perr. (Jaensch, 3, p. 268)	Ambatsch	India		×		×		×					×		0.22–0.23	
Holocalyx Balansae Micheli	Alecrin	Argentina	×				×					×			0.20–0.21	120–125
Icthyomethia piscipula (L.) Kuntze	Jamaica Dogwood	Florida	×		×		×	—					×		0.17–0.18	140–150
Indigofera Zollingeriana Miq.		Philippine Islands	×						×			×	—		0.18	135
Inocarpus edulis Forst. (Höhnel, 1, p. 33)	Boko or Coco Wood	Guiana	×			×	×				×				0.33	
Koompassia excelsa Teub.	Manggis	Philippine Islands	×					×			×				0.55–0.60	42– 45
Laburnum vulgare J. Presl (Wiesner, 5, p. 940)	Goldregen	Europe		×												
Lonchocarpus albiflorus G. Don	Robo blanco	Argentina	×		×		×					×			0.21	118–121
Machaerium Whitfordii Macb.	Negrillo	Colombia	×			×	×						×		0.17–0.18	140–145
" sp.? (*Dalbergia*?)	Jacaranda roxo	Brazil	×					×					×		0.19	128
" sp.? (*Dalbergia*?)	Jacaranda mulatto	"	×					×				×			0.19	128
" sp.? (*Dalbergia*?)	Jacaranda	"	×					×					×		0.18	136
Mezoneurum kauaiense Hillebd.	Uhi-uhi	Hawaii		×					×			×			0.23–0.25	100–110
Milletia pendula Benth.		India	×				×				×				0.24–0.25	98–104

MYROCARPUS FASTIGIATUS Allem.	Incienso	Argentina	×				×				×				0.26	95
" "	Oleo vermelho	Brazil	×				×				×				0.28	90
" FRONDOSUS Allem.	Incienso	Argentina	×				×				×				0.21–0.23	110–118
" "	"	"	×				×				×				0.19	128
" " ?	Cabriuva	Brazil	×				×					×			0.18–0.19	132–136
MYROSPERMUM FRUTESCENS Jacq.	Cereipo	Venezuela	×				×				×				0.25	100–102
" sp.	"	"	×				×				×				0.26–0.28	90– 95
MYROXYLON TOLUIFERUM H.B.K. (*Toluifera balsamum* L.)	Balsamo de Tolu	Colombia	×				×				×				0.23	109
MYROXYLON TOLUIFERUM ?	Balsamo cope	"	×				×				×				0.25	102
OLNEYA TESOTA Gray	Ironwood	Southwestern United States		×				×						×	0.16–0.17	150–160
ORMOSIA CALAVENSIS Azaola		Philippine Islands	×						×	×	×				0.36	70
" ROBUSTA Baker		India	×						×		×				0.37	68– 70
OUGEINIA DALBERGIOIDES Benth.	Sandan	"	×					×				×			0.16	154–160
" "	"	"	×				×					×			0.20	125
PARKIA BIGLANDULOSA Wight & Arn. (Höhnel, 1, p. 38)		Malaya?	×				×								0.20	
PLATYMISCIUM DUBIUM Pittier		Panama	×						×		×				0.23–0.25	102–108
" sp. (No. 428)	Trebo	Colombia	×					×			×				0.27–0.28	88– 94
" sp. (No. 404)	"	"	×				×				×				0.25	98–100
PLATYPODIUM MAXONIANUM Pittier		Panama	×				×				×				0.22–0.24	105–115
PONGAMIA GLABRA Vent. (Solereder, 6, p. 903)		Tropical Asia														
PONGAMIA MITIS Merr.		Philippine Islands	×				×					×			0.16	155–160
PTEROCARPUS ANGOLENSIS DC. (Höhnel, 1, p. 34)	Barwood		×				×								0.25?	
PTEROCARPUS DALBERGIOIDES Roxb.	Andaman Padouk	India	×				×					×			0.22–0.23	112–117
" DRACO L.	Pao sangue	Brazil	×					×				×			0.20–0.21	120–125
" ECHINATUS Pers.	Prickly Narra	Philippine Islands	×					×				×			0.21	120
" ERINACEUS Lam. (Höhnel, 1, p. 34)		Senegal	×				×					×			0.20?	
PTEROCARPUS INDICUS Willd.	Red Narra	Philippine Islands	×				×								0.20–0.21	120–125
" MACROCARPUS Kurz	Padouk	India	×				×					×			0.23–0.24	106–110
" MARSUPIUM Roxb.	Vengai	"	×				×				×				0.21–0.22	115–120
" "	Bija Sal	"	×				×					×			0.23	110

TABLE OF WOODS WITH TIER-LIKE STRUCTURE, SHOWING THE ELEMENTS STORIED, THE REGULARITY AND VISIBILITY OF THE TRANSVERSE LINES ("RIPPLE MARKS"), AND MEASUREMENTS OF TIER-HEIGHT—*Continued*

Scientific name	Common name	Country	Elements storied				Regularity of lines				Visibility				Measurements	
			All elements	Rays not storied	Wood parenchyma cells storied	Fiber pits storied	Regular	Fairly regular	Irregular	Local occurrence	Distinct—fairly so	Barely visible	Lens required	Indistinct with lens	Tier-height in mm.	Number of tiers per inch
LEGUMINOSAE—*Continued*																
PTEROCARPUS ROHRII Vahl?		Brazil	×					×				×			0.26	95
" SANTALINUS L.	Red Sanders	India	×				×					×			0.22	113
PTEROGYNE NITENS Tul. (four specimens)	Ibiraro or Viraro	Argentina	×				×					×			0.25–0.28	90–100
" sp.?	Cereipo	Venezuela	×				×					×			0.26	94
SOPHORA CHRYSOPHYLLA Seem.	Mamani	Hawaii		×				×					×		0.16	155–160
" SECUNDIFLORA Lag.	Frijolita	Southwestern United States		×				×					×	×	0.16	160
SWARTZIA GAILLARDI Pittier		Panama	×					×				×			0.22–0.23	110–115
" PANAMENSIS Benth.		"	×				×				×				0.25	100–102
" TOMENTOSA DC. (Stone and Freeman, 9, p. 55)	Wamara	British Guiana	×					?				×				
TAMARINDUS INDICA L.	Tamarind	Hawaii	×						×			×			0.31	80
TIPUANA SPECIOSA Benth.	Tipa	Argentina	×				×				×				0.20–0.21	120–125
" sp. (No. 897)	"	"	×				×				×				0.18–0.19	130–135
WALLACEODENDRON CELEBICUM Koord.	Banuyo	Philippine Islands	×						×		×				0.33–0.36	70– 75
LYTHRACEAE (see page 260)																
PHYSOCALYMMA SCABERRIMUM Pohl?	Brazilian Tulip	Brazil	×			×	×						×		0.16	160
MALVACEAE																
GOSSYPIUM ARBOREUM L.	Cotton	Costa Rica		×					×			×			0.29	85

Gossypium drynarioides Seem.	Kokio	Hawaii		×	×				×				—	×		
Hibiscus grewiaefolius Hassk.		Philippine Islands	×				×				×				0.33–0.36	70– 75
" macrophyllus Roxb.		Java		×					×							
" similis Blume (M.&J., **7**, I, p. 375)		"		×					×							
Hibiscus tiliaceus L.	Malubago	Philippine Islands	×	—			×	—			×				0.28–0.30	85– 90
Sida densiflora Hook. & Arn.	Loro blanco			×				×			×				0.23	110
Thespesia populnea Corr. (M.&J., **7**, I, p. 389)		India	×	—				×			×			×	0.25	100
MELIACEAE																
Carapa guianensis Aubl.?	Andiroba	South America	×						×		×			×	0.50	50
" obovata Blume (M.&J., **7**, II, p. 200)		Java	×					×				×				
Cedrela sp. (four specimens)	Cedro	Tropical America	×						×	×	×			×	0.45–0.50	50– 55
Chickrassia tabularis A. Juss. (*Chukrasia tabularis* A. Juss.)	Chittagong Wood	India	×						×	×	×				0.31–0.32	78– 82
Entandrophragma Candollei Harms	Sapeli	Africa	×						×	×	×			×	0.5	50
Guarea trichiloides L. (Höhnel, **1**, p. 39)			×				×									
Khaya sp.	African Mahogany	Africa	×						×	×	×			×	0.50	50
Swietenia Mahagoni Jacq.	Mahogany, Caoba	Tropical America	×					×	—	—	×				0.46–0.54	46– 54
MORACEAE																
Ficus altissima Blume		India	×					×			×			×	0.38–0.40	62– 66
" Benjamina L.	Balete	Philippine Islands	×					×			×			×	0.39	64
MORINGACEAE																
Moringia pterygosperma Gärtn. (Höhnel, **1**, p. 35)	Griesholz		×	—					×	×	×					
Moringia sp. (M.&J., **7**, II, p. 514)		Java	×					×			×					
ROSACEAE (see page 260)																
Ferolia guyanensis Aubl.? (*Parinarium* sp.; Höhnel, **1**, p. 43)	Ficatin- or Königsholz	Guiana	×				×									

TABLE OF WOODS WITH TIER-LIKE STRUCTURE, SHOWING THE ELEMENTS STORIED, THE REGULARITY AND VISIBILITY OF THE TRANSVERSE LINES ("RIPPLE MARKS"), AND MEASUREMENTS OF TIER-HEIGHT—*Continued*

Scientific name	Common name	Country	Elements storied				Regularity of lines				Visibility				Measurements	
			All elements	Rays not storied	Wood parenchyma cells storied	Fiber pits storied	Regular	Fairly regular	Irregular	Local occurrence	Distinct—fairly so	Barely visible	Lens required	Indistinct with lens	Tier-height in mm.	Number of tiers per inch
RUTACEAE																
CHLOROXYLON SWIETENIA DC.	Satinwood	India	×					×			×				0.31–0.32	78– 82
SAPINDACEAE																
SAPINDUS SENEGALENSIS Poir. (Höhnel, **1**, 43)		Africa?		×		×	×						×		0.20	
SIMARUBACEAE																
PICRAENA EXCELSA Lindl. (Höhnel, **1**, p. 41; Wiesner, **5**, p. 955)	Jamaica Quassia	West Indies	—	×			?						×			
PICRASMA JAVANICA Blume (M.&J., **7**, II, 84)		Java	×				×				×				0.30	
SIMARUBA AMARA Aubl.	Pao parahyba	Brazil	×					×			×				0.43	58– 60
" GLAUCA DC.	Bitterwood	Florida	×					×	—		×				0.50	51– 52
SURIANA MARITIMA L.?	Palo corra	Curaçao	×					×				×			0.21	120
STERCULIACEAE																
GUAZUMA ULMIFOLIA Lam.	Guasima	Curaçao		×					×			×			0.30–0.31	80– 85
HERITIERA LITTORALIS Ait.	Dungon late	Philippine Islands		×				—	×			×			0.31	80
" MINOR Lam.	Sundri	India		×				—	×			×			0.31–0.32	77– 80
" "	"	"		×				×				×			0.27	92
KLEINHOVIA HOSPITA L.		"	×	—				×				×			0.31–0.33	74– 80

Melochia indica Gray (M.&J., 7, I, p. 469)		Java	×	—				×			×					
Pterocymbium javanicum R.Br. (M.& J., 7, I, p. 440)		"		×				×				×			0.40	
Pterocymbium tinctorium Merr.		Philippine Islands		×	×	×		×			×				0.45–0.50	50– 55
Pterospermum diversifolium Blume		Java		×			×	—			×	—			0.50	
" javanicum Jungh. (M.& J., 7, I, p. 463)		"		×			×	—			×	—			0.50	
Pterospermum suberifolium Lam. (Höhnel, 1, p. 42)		India	×	—				×			×			×	0.30–0.31 (0.25,H.)	80– 85
Pterospermum sp.	Bayok	Philippine Islands	×					×			×				0.38	66
Sterculia foetida L. (M.&J., 7, p. 424)		Java		×	×											
" populifolia Roxb.	Dalibuda	India		×	×			×			×				0.36	70
Tarrietia Argyrodendron Benth.	Crow's-foot Elm	Australia		×				×			×				0.36	70
" javanica Blume	Lumbayao	Philippine Islands		×				×			×				0.36–0.41	60– 70
" sumatrana Miq. (M.&J., 7, I, p. 446)		Java		×				×			×				0.30	
Tarrietia sylvatica (Vidal) Merr.	Dungon	Philippine Islands		×				×			×				0.32–0.33	83– 85
" "	"	" "		×				×				×			0.26–0.28	90– 95
TILIACEAE																
Berria Ammonilla Roxb.		Java	×	—				×			×				0.25	
" quinquelocularis T.&B. (M.& J., 7, I, pp. 492, 496)		"		×					×	×						
Columbia serratifolia DC.	Analin	Philippine Islands	—	×				×			×				0.31–0.33	75– 80
Diplodiscus paniculatus Turcz.	Baloba	" "	×					×			×				0.31–0.33	75– 80
Grewia celtidifolia Juss.		Java		×				×			×					
" laevigata Vahl (M.&J., 7, I, pp. 499, 507)		"		×				×			×				0.23	
Grewia Rolfei Merr.	Danglin	Philippine Islands		×				×				×			0.24–0.25	100–105
" tiliaefolia Vahl		India		×				×				×			0.23	110
Heliocarpus americanus L.	Amor seco	Argentina		×				×				×			0.33	75
" appendiculatus Turcz.		Panama		×	×				×		×				0.38	65
Pentace polyantha Hassk. (M.&J., 7, p. 488)		Java	×					×			×				0.40	
Schoutenia ovata Korth. (M.&J., 7, I, p. 522)		"	—	×				×	—		×	—			0.22	

TABLE OF WOODS WITH TIER-LIKE STRUCTURE, SHOWING THE ELEMENTS STORIED, THE REGULARITY AND VISIBILITY OF THE TRANSVERSE LINES ("RIPPLE MARKS"), AND MEASUREMENTS OF TIER-HEIGHT—*Continued*

Scientific name	Common name	Country	Elements storied				Regularity of lines				Visibility				Measurements	
			All elements	Rays not storied	Wood parenchyma cells storied	Fiber pits storied	Regular	Fairly regular	Irregular	Local occurrence	Distinct—fairly so	Barely visible	Lens required	Indistinct with lens	Tier-height in mm.	Number of tiers per inch
TILIACEAE—*Continued*																
TILIA AMERICANA L.	Basswood	Eastern United States		×				×	—			×		×	0.42–0.45	55–60
" CORDATA Mill. var. JAPONICA		Japan		×				×			—	×		×	0.48	52
" HETEROPHYLLA Vent.	Basswood	Southeastern United States		×				×	—			×		×	0.40–0.41	60–62
" MANDSHURICA Rupr.		China		×				×				×		×	0.45	56
" PUBESCENS Ait. (Record, **8**, p. 76)	Basswood	Eastern United States		×				×	—			×		×	0.41–0.43	58–60
ULMACEAE																
HOLOPTELEA INTEGRIFOLIA (Roxb.) Planch. (*Ulmus integrifolia* Roxb.)		India	×					×					×		0.22–0.23	110–115
ZYGOPHYLLACEAE																
BULNESIA ARBOREA (Jacq.) Engl.	Vera	Venezuela	×				×						×		0.10	250 ±
" SARMIENTI Lorentz	Palo santo	Argentina	×				×						×		0.10	240–250
GUAIACUM COULTERI Gray	Guayacan	West Coast Mexico	×				×						×		0.09	260–270
" OFFICINALE L.	Lignumvitae	West Indies	×				×						×		0.10	250–260
" SANCTUM L.	"	Florida	×				×						×		0.09	260–270
LARREA CUNEIFOLIA Cav. (Solereder, **6**, p. 182)		Argentina?														
LARREA DIVARICATA Cav.	Javilla	"	×				×	—					×		0.09	270–280
PORLIERA HYGROMETRA Ruiz & Pav. (*Guaiacum hygrometricum* Bail.; Höhnel, **1**, p. 40)	Guayac	Chile	×				×						×		0.09–0.10	

SUMMARY

Storied or tier-like arrangement of part or all of the elements is characteristic of many dicotyledonous woods representing a wide range of natural orders and families. The storied structure is found also in the secondary phloëm.

The structure is exhibited on longitudinal sections, typically the tangential, as fine transverse striations ("ripple marks"). These are often visible without a lens.

"Ripple marks" are constant enough in stems of considerable thickness to serve as a valuable diagnostic feature.

In some woods pit areas on the fibers are in seriation. In some instances, also, the cells of the wood parenchyma strands are arranged in a secondary seriation, visible under the lens.

A table is appended giving for each wood the various elements storied, the uniformity and distinctness of the markings, and the height of the tiers.

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